(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 163 076 B1**

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **13.11.91**

(51) Int. Cl.5: **B23Q 35/128**, G05B 19/42, G03C 9/08

(21) Application number: **85104269.7**

(22) Date of filing: **09.04.85**

(54) **Apparatus for producing a three-dimensional copy of an object.**

(30) Priority: **17.04.84 JP 77212/84**
17.04.84 JP 77213/84
08.10.84 JP 210775/84
30.11.84 JP 253486/84

(43) Date of publication of application:
04.12.85 Bulletin 85/49

(45) Publication of the grant of the patent:
13.11.91 Bulletin 91/46

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI LU NL SE

(56) References cited:
EP-A- 0 019 610
EP-A- 0 025 911
EP-A- 0 091 876
DE-A- 2 326 289
DE-A- 2 633 036
DE-A- 2 834 612
US-A- 4 041 476
US-A- 4 158 325
US-A- 4 385 360

Autonation Technique, February 1981, vol 13, no 2, pages 45-49

(73) Proprietor: **KAWASAKI JUKOGYO KABUSHIKI KAISHA**
1-1 Higashikawasaki-cho 3-chome
Chuo-ku Kobe-shi Hyogo-ken(JP)

(72) Inventor: **Okada, Gensuke**
4388-2, Yaho
Kunitachi-shi(JP)
Inventor: **Iijima, Gouhei**
608-215, Kanki
Higashikankicho Kakogawa-shi(JP)

(74) Representative: **Strehl, Schübel-Hopf, Groening**
Maximilianstrasse 54 Postfach 22 14 55
W-8000 München 22(DE)

EP 0 163 076 B1

Description

This invention relates to an apparatus for producing a three-dimensional copy of an object as described in the pre-characterizing portion of claim 1. The object may be, for example, a human body.

It has been proposed to employ a profile machine tool, cast, invertion mold, etc. in order to producing, from the object having a three-dimensional shape, its equivalent three-dimensional copy.

The above proposals have such a disadvantage that the dimensional limitations to the machine tool, cast, etc. restrict an object to such as capable of being molded in a three-dimensional shape, which makes it impossible to copy from an object having a complicated shape and significant uneveness. They also have a disadvantage that if the object is a soft material, the copying thereof requires artistic sense as well as higher skill.

The apparatus recited in the pre-characterizing portion of claim 1 is disclosed in an article entitled "Copying of Object Using Pattern Technique" in AUTOMATION TECHNIQUE, February 1981, Vol. 13, No. 2, pages 45 - 49. Accordingly, a slit optical image projected to an object is picked up by an ITV camera to provide spatial coordinates of the bright lines generated over the object surface, with the possibility of copying the object. This article, however, does not disclose any concrete means for copying the object.

A principal object of this invention is to provide an apparatus which can provide an easy measurement method for producing a three-dimensional copy and makes it possible to produce, with high accuracy, a three-dimensional copy equivalent to or with a certain magnification of an object, regardless of the complexity of the object shape and the hardness thereof.

In order to attain the above object, the present invention is implemented as described in the characterizing portion of claim 1. Preferred features of the apparatus according to claim 1 are included in subclaims 2 and 3.

The features of the present invention will become more apparent from the following description taken in conjunction with the accompanying drawings in which:

Fig. 1A and 1B are a side view and a front view of an embodiment according to this invention;

Fig. 2 shows an image of the ITV camera employed in the embodiment;

Fig. 3 shows the status of a video signal on the image plane as shown in Fig. 2;

Fig. 4 is a block diagram which shows a measurement processing section for the sectional shape in the embodiment;

Fig. 5 is a schematic diagram of a working system for slice cutting in the embodiment.

Hereafter, explanation will be made on an embodiment of this invention with reference to the attached drawings. Figs. 1A and 1B show a part of the arrangement of the embodiment, in which for simplicity of explanation, a model 1 of a simplified human face is employed as an object. Coordinates are set for the model; the coordinate axes are used as references for the irradiation positions of light beams and the positions of the image pick-up device of an optical image. The coordinates are set with an origin G of a bottom center of the model 1, an X-axis extending in the horizontal direction from the origin G in the front view of Fig. 1B, a Y-axis extending in the vertical direction from the origin G in the front view of Fig. 1B and a Z-axis of a vertical center line of the model 1 in the side view of Fig. 1A.

Hereafter, the embodiment of this invention will be explained in more detail. The feature of this embodiment resides in that a slit light irradiation device 90 is provided for irradiating plural slit lights 90a in order to shorten the irradiation time of the object 1.

The slit light irradiating device 90 is constituted by plural light sources, e.g., 10 laser light generators and an optical system, e.g., cylindrical lens or concave mirror, and irradiates to the model 1 plural (e.g. 10) slit lights $90a_1$ - $90a_{10}$ each with a thickness of Δh (e.g. 0.5 mm) and a spreading angle of θ. The slit lights $90a_1$ - $90a_{10}$ each takes as a center line a perpendicular line drawn from the center of the corresponding light source to the vertical center line (Z-axis) of the model 1, and are arranged so that they are irradiated in parallel to each other and at equal intervals, e.g., 30 mm.

An ITV camera 3 as a two-dimensional image pick-up device is arranged at a fixed distance from the slit light irradiation device 90, and so that the optical axis of the camera is directed to the model 1 and forms a predetermined angle with the slit lights $90a_1$ - $90a_{10}$ (For example, an angle of β is formed with the slit light $90a_5$). Further, it is assumed that the effective view angle of the ITV camera 3 is α, the point where the perpendicular line drawn from the principal point of the lens of the camera to the Z-axis intersects the Z-axis is G, the segment perpendicularly intersecting the X-axis and the Z-axis is a Y-axis, and the point G is the origin of each co-ordinate axis.

The slit light irradiation device 90 and the ITV camera 3 are fixedly mounted on a rack 4 which is slidably guided on a guide post; the rack 4 is attached on a ball nut 6 screwed with a ball screw shaft 5. A step motor (not shown) connected with the ball screw shaft 5 stepwise drives the ball nut 6 up and down by

the thickness Δh of the slit light. Thus, slit light is stepwise irradiated to the model.

In order to irradiate the entire periphery of the model 1 with the slit light 90a and pick up the resultant optical image, plural slit light irradiation devices 90 and ITV cameras 3 associated therewith may be arranged so as to surround the model 1.

When, in this case, the distance from each ITV camera to the Z-axis as the center line of the model 1 is equally set, and its optical magnification is also equally set, the operation for forming the NC data on the basis of the measurement result can be simplified since the optical images corresponding to the slit lights picked up by the associated ITV cameras 3 can be directly compared. However, this is not an indispensable requisite. For example, with only the shape of a certain section of the object being previously and actually measured, by comparing the thus obtained data with the data produced from the picking up of the above section by the respective ITV cameras 3, it is also possible to calibrate the measurement data of each camera.

Fig. 2 shows the optical image of the slit lights 90a irradiated to the model 1 which is picked up by the ITV camera 3. When, with the ITV camera 3 arranged so that the direction of its scanning lines is parallel to the plane formed by the X-axis and Z-axis, i.e., X-Z plane, the optical images corresponding to the slit lights 90a irradiated to the model 1 are picked up by the ITV camera 3, 10 arch slit images are provided as shown in Fig. 2 The point P'i included in the slit image in Fig. 2 is an image of the point Pi in Figs. 1A and 1B, and corresponds to any one point of the slit light irradiated to the surface of the model 1. The co-ordinates y and z corresponds to the X axis and Z axis in Figs. 1A and 1B. Incidentally, in Fig. 2, S_1 - S_i - S_r designate scanning lines of the ITV camera 3 and Ka is a threshold value for digitizing the picked-up signal into two values of brightness (high) and darkness (low).

In order to acquire an optical section from the image picked up by the ITV camera 3 as shown in Fig. 2, there will be explained means for the co-ordinates of the point Pi relative to the X-axis, Y-axis and Z-axis. As shown in Fig. 2, one image plane of the ITV camera 3 is formed by scanning the image signal from ITV camera 3 on r (generally, 250 - 500) scanning lines. These scanning lines are referred to S_1, S_2, S_3 - S_i - S_r from left in accordance with the scanning order of the image signal.

The pick-up of the optical image of the model 1 by the ITV camera 3 provides an output signal as shown in Fig. 3. The output signal is outputted in such a way that, as shown in Fig. 3. first, an image plane starting signal V_{BL} (hereinafter referred to as vertical synchronizing signal) is outputted, next a first horizontal scanning starting signal (hereinafter referred to as horizontal synchronizing signal) is outputted and thereafter the image signal in accordance with the brightness or darkness of the optical image is scanned on the scanning line S_1 within a fixed time ta. After the completion of the first scanning, a second horizontal synchronization H_{BL} is outputted and the image signal is scanned on the scanning line S_2. Thereafter, the scanning of the image signal is repeated until the scanning line S_r in the same manner. Thus, one image plane is accomplished.

Fig. 4 shows a block diagram of a control circuit for acquiring the co-ordinates (xi, yi, zi) of the light spot Pi of Fig. 2, relative to the X axis, Y-axis and Z-axis, using the ITV camera 3. In Fig. 4, 3 is the ITV camera, and 109 is a synchronization separating circuit in which the image signal S corresponding to the optical image of the model 1 which is obtained by the irradiation of the slit light 90a and picked up by the ITV camera and is inputted together with the horizontal synchronizing signal H_{BL} and the vertical synchronizing signal V_{BL} is separated from H_{BL} and V_{BL}.

101 designates a counter having a count input terminal (IN) coupled with the horizontal synchronizing signal H_{BL} from the synchronization separating circuit 109 and a reset input terminal (RESET) coupled with the vertical synchronizing signal V_{BL}. The counter 101 is reset to 0 by the vertical synchronizing signal V_{BL} produced prior to the scanning of one image plane and counts the number of the horizontal synchronizing signals H_{BL} each produced prior to the start of the scanning on each scanning line S_1 - S_r. The count of the counter 101 represents the number of the scanning line on which the video signal from the ITV camera is scanned.

102 designates an oscillation circuit which continuously outputs a pulse each time interval ta/m resulting from the division of the time required to scan one scanning line into m equal parts. The pulses produced from the oscillator 102 are counted by a counter, which is reset to 0 by the horizontal synchronizing signal H_{BL}.These pulses are counted by the counter 103 until the horizontal synchronizing signal H_{BL} for the subsequent scanning line is produced. Thus, the scanning point on the image plane of the ITV camera 3 is acquired. The number of the pulses counted by the counter 103 is stored in a memory circuit 107 through a gate circuit.

The image signal of the ITV camera 3, which has been separated from the vertical synchronizing signal V_{BL} and the horizontal synchronizing signal H_{BL} in the synchronizing separation circuit 109, is converted into a digital signal having two values of brightness "1" and darkness "0" (hereinafter referred to as digitized

signal) in a digitizing circuit 108 using a predetermined signal level Ka (Fig. 2) as a reference level. Thus, the bright slit optical image portions of the outer periphery of the model 1 is represented by "1" and the other portions thereof is represented by "0". This digitized signal is applied to the respective gate switching control terminals N of gate circuits 104, 105, and the gate circuits 104, 105 are closed only when the digitized signal is "1", thereby storing the contents of the counters 101, 103 into memory circuits 106, 107, respectively. Thus, there can be stored the scanning line number (content of the counter 101) and the position of a certain scanning line (content of the counter 103) when having picked up the optical image of the model 1. It is now assumed that the content of the memory circuit 106 is ΔYi and the content of the memory circuit 107 is ΔZi.

Further, as the case may be, plural ΔYi's and ΔZi's are provided for one scanning line; all of these ΔYi - ΔYip and ΔZi - ΔZip are stored in the memory circuits 106, 107. There may be the light spots of the plural slit optical images on one scanning line. Therefore, the identification of ΔYi's and ΔZi's is made in synchronism with the lighting commands of the slit lights $90a_1$ - $90a_{10}$, which are sequentially applied to the slit light irradiation device 90 from a microcomputer 110.

The acquisition of ΔYi and ΔZi allows the X and Y co-ordinates (Xi, Yi) of the point Pi of the model 1 to be acquired in the following manner, referring to Fig. 22A.

The point Pi as shown in Figs. 1A and 1B is an intersection of a segment $\overline{AQ}$ and a segment Z = ZL, and Xi is provided by the following equations:

$$\begin{cases} Zi = ZL \\ Zi = -\dfrac{\overline{GQ}}{L}X + \overline{GQ} \end{cases} \quad \cdots\cdots \quad (1)$$

$$\therefore\ Xi = -\frac{L}{\overline{GQ}}(\overline{GQ} - ZL) \quad \cdots\cdots \quad (2)$$

where

$\overline{GQ}$: distance between points G and Q,

L: distance between the Z-axis and the center of the ITV camera lens

ZL: distance between the slit light $90a_2$ and the X-axis.

$\overline{GQ}$ in equation (2) is provided by

$$GQ = L\tan(\alpha + \gamma - \frac{\alpha}{m} \cdot \Delta Zi) \quad \cdots\cdots \quad (3)$$

where

α: view angle of the ITV camera

γ: angle formed by the view of the bottom end of the ITV camera with the X-axis

m: sampling time.

Yi is provided by

$$Yi = (L - Xi)\tan(\frac{\alpha}{2} - \frac{\alpha}{r} \cdot \Delta Yi) \quad \cdots\cdots \quad (4)$$

where

r: total number of scanning lines on one image plane

Xi: value provided by equations (2) and (3).

The operations of equations (2), (3), (4) are carried out by the microcomputer 110 and the result thereof is stored in a memory 111.

After all of the X and Y co-ordinates (Xi, Yi) relative to one image plane of the ITV camera 3 have been calculated and the result thereof has been stored, the rack 4 as shown in Fig. 1A is driven by the step motor (not shown) by a thickness Δh of the slit light in order to perform the same processing as mentioned above. The rack 4 is moved by the interval Δh of the adjoining slit lights.

The above explanation has been made for one measurement device including the ITV camera. When the three-dimensional measurement of the entire periphery of the model 1 is intended, a plurality of the ITV cameras 3 are arranged at an even distance from the Z-axis of the model 1 together with measurement processing parts associated therewith to acquire the corresponding ΔYi's and ΔZi's. The data of ΔYi's and ΔZi's relative to each camera are inputted into the microcomputer 110 to calculate the corresponding co-ordinates (Xi, Yi), and the result of the calculation is stored in the memory 111. Thus, the three-dimensional measurement of the entire periphery of the model 1 is performed. Then, the plurality of ITV cameras provide plural image planes, which give rise to some overlapping between the image planes adjacent to each other. However, this overlapping can be obviated by previously setting the range of image pick-up of each ITV camera. For example, where n ITV cameras are arranged around the model 1 at regular intervals, the image pick-up range can be set about the optical axis of each ITV camera 3 in a range of ±360/2n relative to the Z-axis. Further, in this embodiment, in order to simplify the operation processing, all of the ITV cameras are shifted to be situated at the same level of the Z-axis.

Next, explanation will be made on the manner of producing or copying the three-dimensional shape of the model 1 on the basis of the thus obtained optical spots (Xi, Yi) thereof. It is now assumed that the scanning lines of the plurality of ITV cameras 3_1 - 3_n are 1Si - nSi, respectively, and the co-ordinates of the slit lights $90a_1$ - $90a_{10}$ relative to the scanning line 1Si, stored in the memory 111 are $(Xi90a_1, Yi90a_1)\ell Si$ - $(Xi90a_{10}, Yi90a_{10})$ 1Si. In this embodiment, as shown in Fig. 5, ten NC laser cutting machines 150_1 - 150_{10} for sheet cutting constitutes a working system which is controlled by the NC commands from the microcomputer 110 connected with these cutting machines. After a sheet with a thickness of Δh is set, in each laser cutting machine 150_1 - 150_{10} the above co-ordinate commands $(Xi90a_1, Yi90a_1)1S_1$ -$(Xi90a_{10}, Yi90a_{10})1S_1$ are applied to the cutting machines, respectively to start the cutting of the sheets. Next, the co-ordinate commands $(Xi90a_1, Yi90a_1)1S_2$ -$(Xi90a_{10}, Yi90a_{10})\ell S_2$ are applied to the laser cutting machines 150_1 - 150_{10}, respectively, to perform the respective cuttings. Such an operation is repeated until the execution of the co-ordinate commands $(Xi90a_{10}, Yi90a_{10})$ $1S_r$. After the completion of the NC cutting relating to the ITV camera 3_1, the NC cutting based on the co-ordinate commands $(Xi90a_1, Yi90a_1)2S_1$ - $(Xi90a_{10}, Yi90a_{10})2Sr$ is performed for the ITV camera 3_2. The similar cutting is repeated until the ITV camera 3_n. Thus, there are provided at a first measurement point templates each with a thickness Δh having the same shape as the sectional shape of the model relative to each of the slit light planes $90a_1$ -$90a_{10}$. Subsequently, the processing is made at a second measurement position. The repetition of such a processing by the predetermined times of measurement provides the templates corresponding to all of the sectional shapes relative to the model.

The stacking of the thus formed templates is done in the measurement order, e.g. a fixing using adhesive allows the model to be easily copied.

In accordance with this embodiment, a high speed operation processing can be realized since a plurality of slit lights are arranged so as to be irradiated to the Z-axis of the model so that the slit light sources are shifted by a short distance and the irradiation time of the slit light is reduced. Moreover, the scanning lines of the ITV cameras are arranged in a vertical direction so that twice or more resolution in the vertical direction can be provided as compared with that in the horizontal direction, thereby improving the measurement accuracy for the model extending in the vertical direction such as a person figure.

Incidentally, although in this embodiment, in order to simplify the operation processing, all of the ITV cameras are shifted to be situated at the same level with respect to the Z-axis, this is not an indispensable requisite. For example, by applying the measurement result of the height of each ITV camera through an encoder, for example, to a microcomputer, the data (Xi, Yi) provided by each ITV camera are matched to the same height. Enlarging or reducing the thickness of the sheet to be cut by the NC cutting machine to $N\Delta h$ or $\Delta h/N$ by multiplying the data (Xi, Yi) N times or 1/N times permits the shape of the model to be enlarged or reduced in any size.

Claims

1. An apparatus for producing a three-dimensional copy of an object (1) having a three-dimensional shape, comprising:

   irradiation means (90) for irradiating light beams (90a) lying in a predetermined plane (X-Y) onto the surface of said object (1);

   image pick-up means (3) for picking up the optical image reflected from the surface of said object (1);

   calculation means (100, 110) for calculating a section shape of said object (1) in the plane (X-Y) of the irradiated light beam (90a) based upon the data acquired by the image pick-up means (3); and

means (4, 5 to 8) for repeatedly shifting said irradiation means (90) by a distance corresponding to the thickness (Δh) of said light beam (90a), in a direction (Z) perpendicular to the plane (X-Y) containing the light beam in order to acquire sequentially in the direction (Z) of said shifting the respective adjacent section shapes of said object (1);

wherein means (150) are provided for forming templates from a sheet material having shapes corresponding to the sections thus acquired by said calculation means, and for marking said templates in correct sequence and orientation, wherein the size of each template is in the same ratio to the size of the corresponding section of the object as the thickness of the sheet is to the thickness of the light beam,

thereby enabling production of an either real or scaled size three-dimensional copy of said object (1) by stacking said templates;

characterized in that

said irradiation means (90) is constituted by a plurality of light sources and irradiates onto the object (1) a plurality of slit lights, each having a predetermined thickness (Δh) and a predetermined spreading angle (θ), in parallel to each other and at equal intervals, that

said image pick-up means (3) are arranged at a fixed distance from said irradiation means (90) so that the optical axis of the camera forms a predetermined angle (β) with one of the slit lights (90a5), and that

said calculation means (100, 110) identifies the coordinates of the points (Pi) being irradiated on the surface of the object (1) in synchronism with the lighting commands of the slit lights (90a) which are sequentially applied to said light sources of the irradiating means (90).

2. An apparatus according to claim 1, characterized in that said image pick-up means is an ITV camera (3) arranged so that the direction of its scanning lines is perpendicular to said plane (X-Y) of said slit lights (90a).

3. An apparatus according to claim 1, characterized in that said image pick-up means is an ITV camera (3), and that said calculation means includes

a separation circuit (109) which separates the image signal (S) which is picked up by the ITV camera (3) from a horizontal synchronizing signal (H_{BL}) and a vertical synchronizing signal (V_{BL}),

a first counter (101) having a count input terminal (IN) supplied with the horizontal synchronizing signal (H_{BL}) from the separating circuit (109) and a reset input terminal (RESET) supplied with the vertical synchronizing signal (V_{BL}) so that the count of the counter (101) represents the number of the scanning line on which the image signal from the ITV camera is scanned,

a second counter (103) which is reset by the horizontal synchronizing signal (H_{BL}) and which counts the pulses from an oscillating circuit (102) which continuously outputs a pulse each time interval (ta/m) resulting from the division of the time required to scan one scanning line into equal parts (m),

a first gate circuit (104) which is supplied with a digitized image signal from the ITV camera and the output of said first counter (101),

a second gate circuit (105) which is supplied with the digitized image signal of the ITV camera and the output of said second counter (103), and

first and second memories (106, 107) storing the contents of said first and second counters (101, 103), respectively.

Revendications

1. Dispositif pour réaliser une copie en trois dimensions d'un objet (1) ayant une forme tridimensionnelle, comprenant:

des moyens d'irradiation (90) pour projeter sur la surface dudit objet (1) des faisceaux lumineux (90a) situés dans un plan (X-Y) prédéterminé;

des moyens capteurs d'image (3) pour capter l'image optique réfléchie par la surface dudit objet (1);

des moyens calculateurs (100, 110) pour calculer la forme de la coupe dudit objet (1) dans le plan (X-Y) du faisceau lumineux projeté (90a) sur la base des données acquises par les moyens capteurs d'image (3); et

des moyens pour déplacer à répétition lesdits moyens d'irradiation (90) d'une distance correspondant à l'épaisseur (Δh) dudit faisceau lumineux (90a), dans une direction (Z) perpendiculaire au plan (X-Y) contenant le faisceau lumineux, afin d'acquérir successivement, dans la direction (Z) dudit déplace-

ment, les formes des coupes adjacentes respectives dudit objet (1);

dispositif dans lequel des moyens (150) sont prévus pour former, à partir d'un matériau en feuille, des gabarits ayant des formes correspondant aux coupes ainsi acquises par lesdits moyens de calcul, et pour marquer ces gabarits dans l'orientation et dans l'ordre corrects, les dimensions de chaque gabarit étant, aux dimensions de la coupe correspondante de l'objet, dans le même rapport que l'épaisseur de la feuille à l'épaisseur du faisceau lumineux,

rendant ainsi possible la réalisation d'une copie tridimensionnelle dudit objet (1), en grandeur naturelle ou proportionnée, par empilage desdits gabarits;

caractérisé

en ce que lesdits moyens d'irradiation (90) sont constitués par plusieurs sources lumineuses et projettent sur l'objet (1) plusieurs faisceaux séparés, ayant chacun une épaisseur (Δh) prédéterminée et un angle d'évasement (θ) prédéterminé, parallèlement les uns aux autres et à intervalles égaux,

en ce que lesdits moyens capteurs d'image (3) sont disposés à une distance fixe des moyens d'irradiation (90), de sorte que l'axe optique de la caméra forme un angle (β) prédéterminé avec l'un des faisceaux séparés (90a5),

et en ce que lesdits moyens calculateurs (100, 110) identifient les coordonnés des points (Pi) qui sont irradiés sur la surface de l'objet (1) en synchronisme avec les commandes d'allumage des faisceaux séparés (90a) qui sont appliquées successivement auxdites sources lumineuses des moyens d'irradiation (90).

2. Dispositif selon la revendication 1, caractérisé en ce que les moyens capteurs d'image sont constitués par une caméra de télévision industrielle (3) disposée de sorte que la direction de ses lignes de balayage soit perpendiculaire audit plan (X-Y) desdits faisceaux séparés (90a).

3. Dispositif selon la revendication 1, caractérisé en ce que lesdits moyens capteurs d'image sont constitués par une caméra de télévision industrielle (3), et en ce que lesdits moyens calculateurs comprennent

un circuit de séparation (109) qui sépare le signal (S) d'image qui est capté par la caméra de télévision industrielle (3) d'avec un signal de synchronisation horizontale (H_{BL}) et un signal de synchronisation verticale (V_{BL}),

un premier compteur (101) comportant une borne d'entrée de comptage (IN) à laquelle est applique le signal de synchronisation horizontale (H_{BL}) provenant du circuit de séparation (109) et une borne d'entrée de remise à l'état initial (RESET) à laquelle est appliqué le signal de synchronisation verticale (V_{BL}), de sorte que le compte du compteur (101) représente le numéro de la ligne de balayage sur laquelle est balayé le signal d'image provenant de la caméra de télévision industrielle,

un second compteur (103) qui est remis à l'état initial par le signal de synchronisation horizontale (H_{BL}) et qui compte les impulsions en provenance d'un circuit oscillant (102) qui délivre de façon continue une impulsion à chaque intervalle de temps (ta/m) résultant de la division en parties égales (m) du temps nécessaire pour balayer une ligne de balayage,

un premier circuit porte (104) auquel sont appliqués un signal d'image numérisé provenant de la caméra de télévision industrielle et le signal de sortie dudit premier compteur (101),

un second circuit porte (105) auquel sont appliqués le signal d'image de la caméra de télévision industrielle numérisé et le signal de sortie dudit second compteur (103), et

des première et seconde mémoires (106, 107) qui mémorisent respectivement les contenus desdits premier et second compteurs (101, 103).

Patentansprüche

1. Vorrichtung zur Herstellung einer dreidimensionalen Kopie eines Objekts (1) von dreidimensionaler Gestalt, umfassend:

eine Bestrahlungseinrichtung (90) zum Bestrahlen der Oberfläche des Objekts (1) mit in einer vorbestimmten Ebene (X-Y) liegenden Lichtstrahlen (90a);

eine Bildaufnahmeeinrichtung (3) zur Aufnahme des von der Oberfläche des Objekts (1) reflektierten optischen Bildes;

eine Recheneinrichtung (100, 110), die basierend auf den von der Bildaufnahmeeinrichtung (3) ermittelten Daten eine Schnittform des Objekts (1) in der Ebene (X-Y) der ausgestrahlten Lichtstrahlen (90a) berechnet; und

eine Einrichtung (4, 5 - 8) zur wiederholten Verschiebung der Bestrahlungseinrichtung (90) um eine

der Dicke (Δh) des Lichtstrahls (90a) entsprechende Distanz in einer Richtung (Z) senkrecht zu der den Lichtstrahl enthaltenden Ebene (X-Y), um die jeweils benachbarten Schnittformen des Objekts (1) sequentiell in Richtung (Z) der Verschiebung zu ermitteln;

wobei eine Einrichtung (150) vorgesehen ist, die aus einem Blattmaterial Modelle bildet, deren Formen mit den von der Recheneinrichtung ermittelten Schnitten übereinstimmen, und diese in der richtigen Reihenfolge und Ausrichtung markiert, wobei die Größe jedes Modells zu der Größe des entsprechenden Schnitts des Objekts in dem gleichen Verhältnis steht wie die Dicke des Blatts zu der Dicke des Lichtstrahls,

wodurch die Herstellung einer 1:1 oder maßstäblichen dreidimensionalen Kopie des Objekts (1) durch Übereinanderstapeln der Modelle ermöglicht wird;

dadurch gekennzeichnet,

daß sich die Bestrahlungseinrichtung (90) aus mehreren Lichtquellen zusammensetzt und das Objekt (81) mit einer Vielzahl von Lichtbändern parallel zueinander und in gleichen Abständen bestrahlt, wobei jedes Lichtband eine vorbestimmte Dicke (Δh) und einen vorbestimmten Ausbreitungswinkel (θ) aufweist,

daß die Bildaufnahmeeinrichtung (3) in einem festen Abstand von der Bestrahlungseinrichtung (90) angeordnet ist, so daß die optische Achse der Kamera mit einem der Lichtbänder (90a5) einen vorbestimmten Winkel (β) bildet, und

daß die Recheneinrichtung (100, 110) die Koordinaten der bestrahlten Punkte (Pi) auf der Oberfläche des Objekts (1) synchron mit den den Lichtquellen der Bestrahlungseinrichtung (90) sequentiell zugeführten Lichtbefehlen der Lichtbänder (90a) identifiziert.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Bildaufnahmeeinrichtung eine ITV-Kamera (3) ist, die so angeordnet ist, daß die Richtung ihrer Abtastlinien rechtwinklig zu der Ebene (X-Y) der Lichtbänder (90a) steht.

3. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Bildaufnahmeeinrichtung eine ITV-Kamera (3) ist, und daß die Recheneinrichtung umfaßt:

einen Trennschaltkreis (109), der das von der ITV Kamera (3) aufgenommene Bildsignal (S) von einem Horizontalsynchronsignal (H_{BL}) und einem Vertikalsynchronsignal (V_{BL}) trennt,

einen ersten Zähler (101), der einen mit dem Horizontalsynchronsignal (H_{BL}) des Trennschaltkreises (109) versorgten Zähleingangsanschluß (IN) und einen mit dem Vertikalsynchronsignal (V_{BL}) versorgten Rückstelleingangsanschluß (RESET) aufweist, so daß der Zählstand des Zählers (101) die Nummer der Abtastlinie darstellt, an der das Bildsignal der ITV-Kamera abgetastet ist,

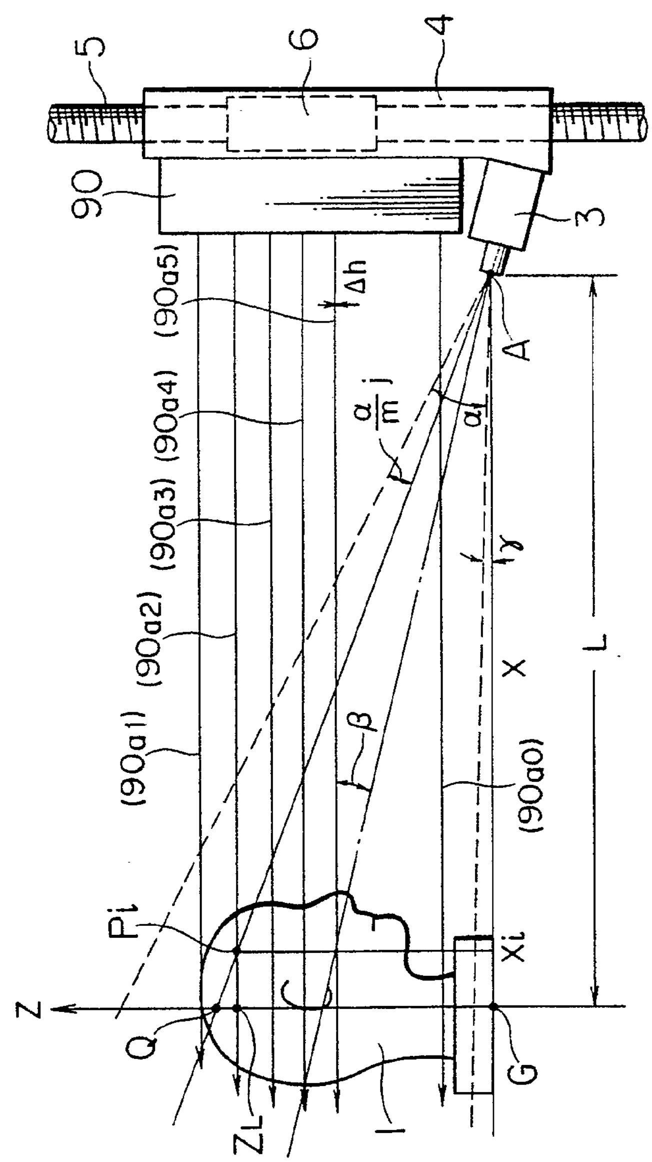
einen zweiten Zähler (103), der von dem Horizontalsynchronsignal (H_{BL}) zurückgesetzt wird und die Impulse eines Oszillatorkreises (102) zählt, der ständig Impulse in jedem Zeitinterval (ta/m) aussendet, das aus der Teilung der zur Abtastung benötigten Zeit einer Abtastlinie in gleiche Abschnitte (m) hervorgeht,

eine erste Torschaltung (104), die mit einem digitalisierten Bildsignal der ITV Kamera und dem Ausgangssignal des ersten Zählers (101) versorgt wird,

eine zweite Torschaltung (105), die mit dem digitalisierten Bildsignal der ITV Kamera und dem Ausgangssignal des zweiten Zählers (103) versorgt wird, und

erste und zweite Speicher (106, 107), die den Inhalt des ersten bzw. des zweiten Zählers (101, 103) speichern.

FIG. 1A



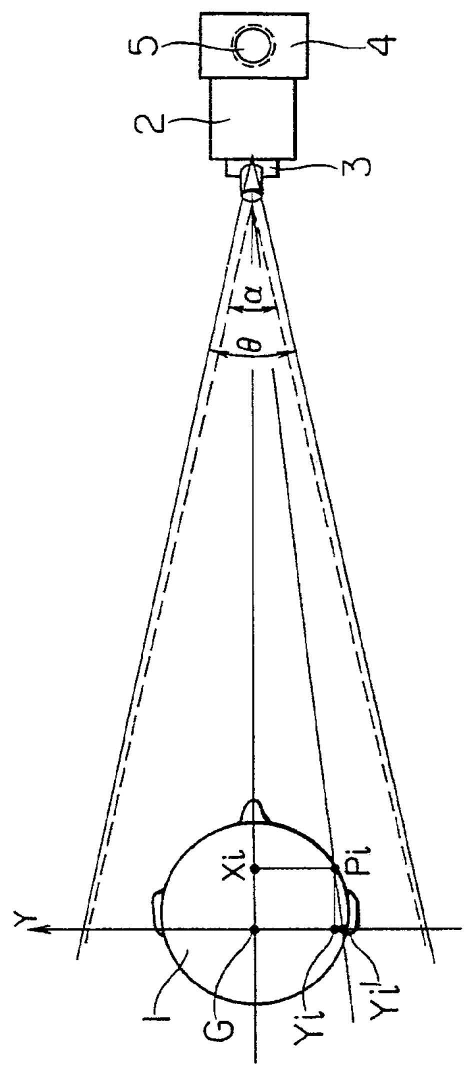


FIG. 1B

FIG. 2

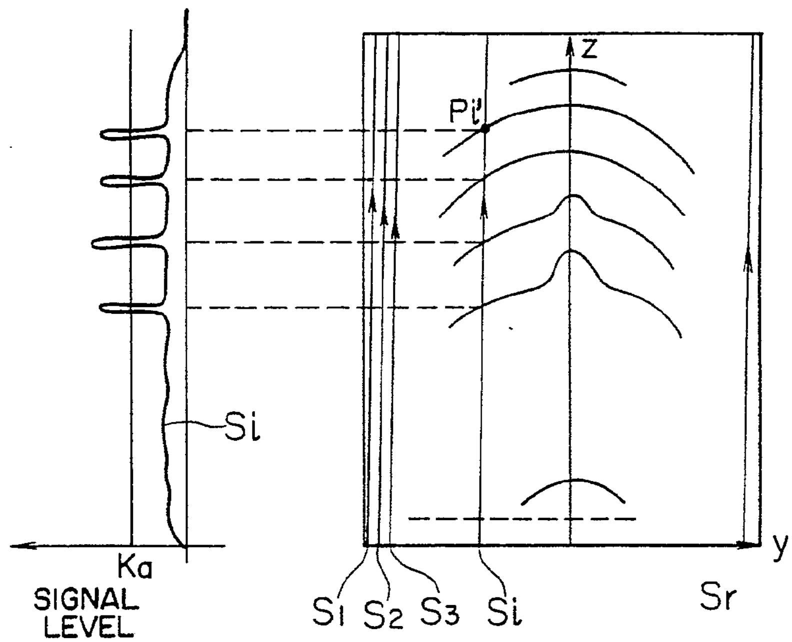


FIG. 3

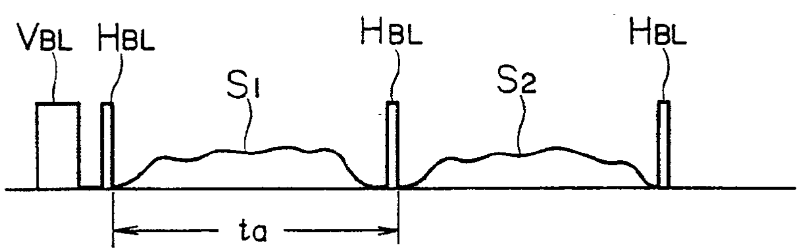


FIG. 4

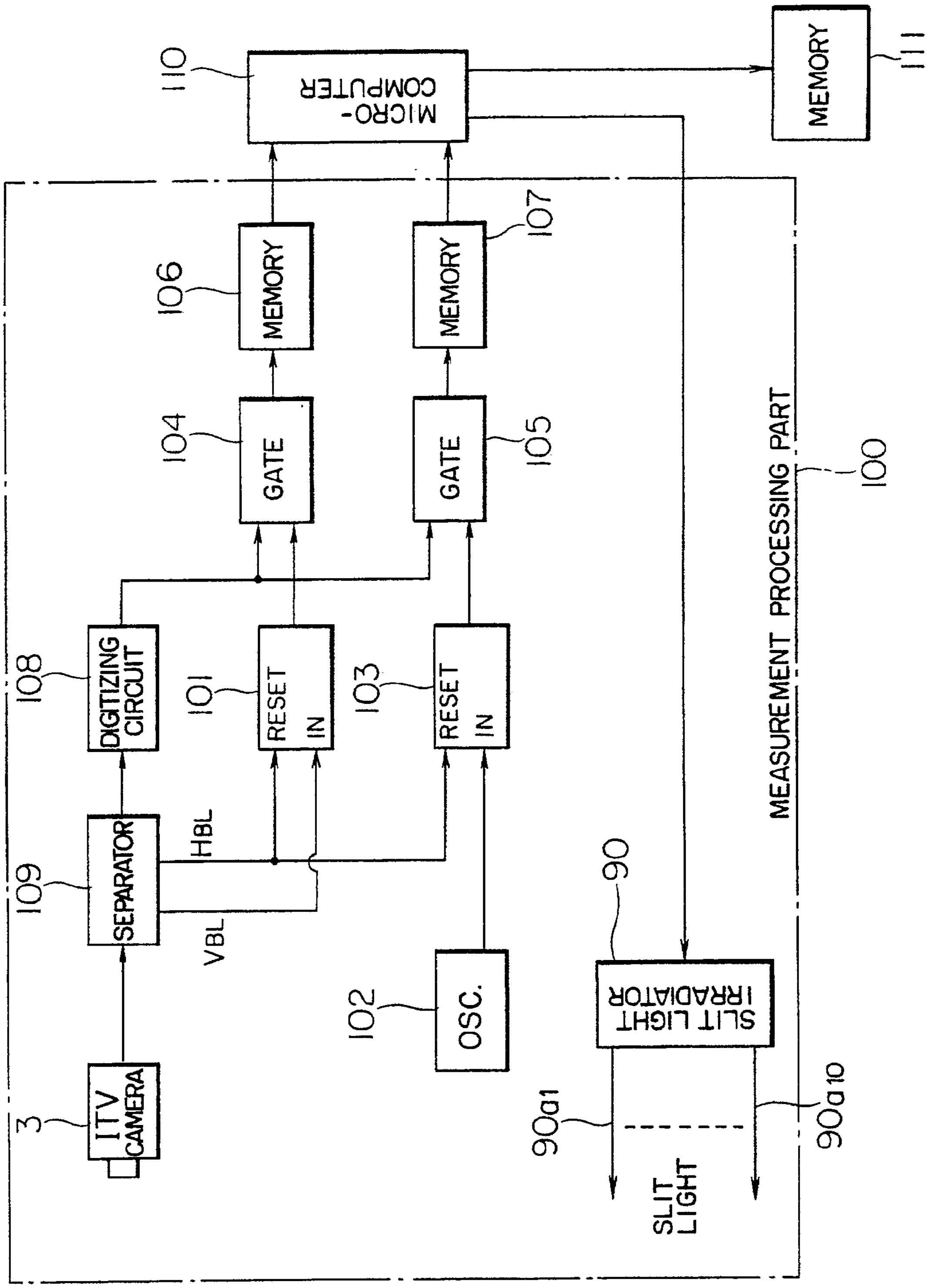
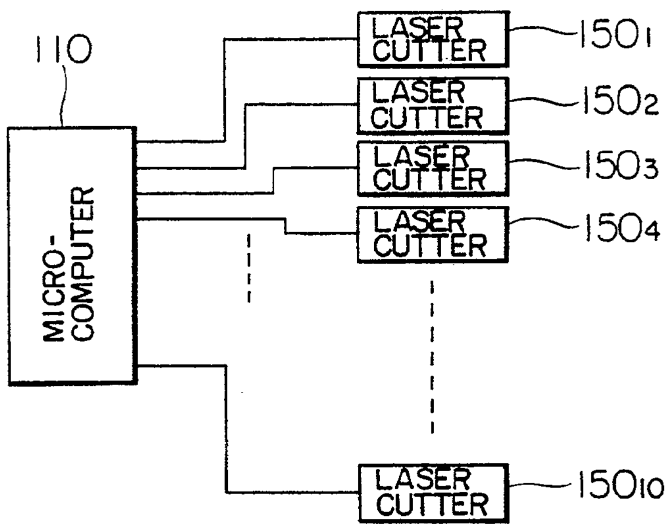

3
ITV CAMERA
109
SEPARATOR
HBL
VBL
108
DIGITIZING CIRCUIT
101
RESET
IN
103
RESET
IN
102
OSC.
104
GATE
105
GATE
106
MEMORY
107
MEMORY
110
MICRO-COMPUTER
MEMORY
111
90
SLIT LIGHT IRRADIATOR
90a1
90a10
SLIT LIGHT
MEASUREMENT PROCESSING PART
100

FIG. 5


110
MICRO-
COMPUTER
LASER
CUTTER
150_1
LASER
CUTTER
150_2
LASER
CUTTER
150_3
LASER
CUTTER
150_4
LASER
CUTTER
150_{10}